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SOFT-GROUND ARRESTING OF CIVIL AIRCRAFT - INFLUENCE OF GRAVEL DEPTH AND TYRE INFLATION PRESSURE

by

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MINISTRY OF TECHNOLOGY
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SUMMARY

This Report describes the arresting trials carried out with a Lightning aircraft to examine the influences of gravel depth and tyre inflation pressure on deceleration.

The mean decelerations achieved at normal main wheel tyre pressures of 260 lb/in^2 in a 30 inch depth of $\frac{3}{4}$ inch - $\frac{1}{4}$ inch rough irregular gravel have been compared with previous results in depths of 12 inches and 18 inches. They show that mean deceleration can be increased by an increase in gravel depth but not in direct proportion and that the effectiveness of increased depth is greatest at lower aircraft speeds.

Mean decelerations achieved at main wheel tyre pressures of 190 lb/in^2 were lower than those at 260 lb/in^2 but the difference was only slight.

Compaction of the gravel occurred due to increased depth and to the fact that the gravel had laid undisturbed for a long period. It is recommended that harrowing a gravel arrester to the full depth would be worthwhile about every 6 months.

Departmental Reference: EP 509

CONTENTS

1 INTRODUCTION

Arresting trials with a Lightning aircraft in 12 inch and 18 inch gravel depths and a Canberra aircraft in 18 inch and 30 inch gravel depths have been described in an earlier Report[1].

The lengthening of the R.A.E. experimental arrester from 400 ft to 640 ft and the increase in gravel depth from 18 inches to 30 inches to test the Canberra gave an opportunity to test the Lightning at higher entry speeds and to check the influence of tyre inflation pressure and increased gravel depth on mean decelerations.

2 ARRESTER DETAILS

The gravel depth pattern is shown in Fig.1, tapering from 3 inches deep at entry to 30 inches deep at 200 ft then continuing at a constant 30 inch depth up to 640 ft. In plan the arrester is tapered from 27 ft wide at the threshold to 44 ft wide at the exit.

3 LIGHTNING TRIALS

The programme was planned to establish the influence of gravel depth and tyre inflation pressure with the minimum number of runs. Unbraked entries had previously been made with the Lightning in an 18 inch depth over a range of speeds from 23 knots to 71 knots. It was reasoned that three unbraked runs at the previous all up weight of 26000 lb and at two main wheel tyre pressures might be adequate. The widest possible range of main wheel tyre pressures at this weight was 260 lb/in^2 and 190 lb/in^2 with corresponding nose wheel tyre pressures of 240 lb/in^2 and 180 lb/in^2.

As before, the true aircraft speed during each arrest was determined by means of a 35 mm Vinten camera, film speed 200 frames per second, using distance markers placed at 5 ft intervals alongside the arrester. An additional check on entry speed was made by two sets of photocells, 10 ft apart, coupling to a timing box. A SFIM (Electrical Mechanisms Ltd.) recorder was mounted in a bay behind the pilot's cockpit to provide a deceleration/time curve.

The results of the trials are listed in Table 1.

4 ANALYSIS OF RESULTS

4.1 Influence of gravel depth and tyre inflation pressure

Mean decelerations are plotted against entry speed in Fig.2 and, for comparison, the curves for the previous Lightning trials in gravel depths of 12 inches and 18 inches are also plotted.

Increases in gravel depth are shown to give an increase in mean deceleration though they are not in proportion to depth increase. The deceleration/distance curves (Fig.3) indicate that the increasing of the gravel depth from 18 inches to 30 inches makes very little difference to the pitching of the aircraft and this was confirmed by the decelerometer traces. The pilot, who did all seven trials, reported the arrests to be smooth and comfortable in every case, noticing only the peak deceleration just prior to the aircraft stopping. These peaks were slightly higher in the 30 inch depth than in the 18 inch depth.

Lowering the main wheel tyre pressure from 260 lb/in^2 to 190 lb/in^2 resulted in lower mean decelerations though the difference was only slight. It is clear that the combination of two inflation pressures and a small number of trials on single-wheel undercarriage units is insufficient to enable positive conclusions to be drawn about the likely influence of the tyre pressure on the stopping of all classes of civil aircraft.

Curves of mean deceleration from a given speed to the stopping point in the full 30 inch depth of gravel, and of instantaneous deceleration at a given speed, are given for both tyre pressures in Figs.4 and 5. They were derived from the data in Tables 2 and 3 by averaging the speeds in several runs at given distances from the stopping point for the parts of the runs in the full depth, plotting smooth curves of average speed v. distance from stopping point for both tyre pressures, and calculating the mean and the instantaneous decelerations at points along the curves. Composite curves for the Lightning aircraft and the model in a full 18 inch depth of gravel, similarly derived in Ref.1 are also shown in Figs.4 and 5. Comparison of the curves indicates the relative effectiveness of gravel depth and tyre inflation pressure. The instantaneous deceleration curves in Fig.5 show that the influence of the higher tyre pressure is evident only towards the end of an arrest, i.e. in the low speed region where the peak deceleration is developed. On the other hand the increased gravel depth shows a general improvement in deceleration though the greatest gain was also in the region of the peak deceleration point.

4.2 Gravel compaction

Gravel compaction was first suspected when, after an enforced interval of four months in the trials programme, Trial 3 was made with the main wheel tyre pressures at 260 lb/in^2. Although the entry speed was slightly higher than that in Trial 2 the mean deceleration fell from 0.70 g to 0.64 g in spite of the higher tyre pressure. In Trial 4, also at a tyre pressure of 260 lb/in^2, the mean deceleration jumped to 0.75 g in spite of the fact that the entry speed was 2 knots higher. A check was therefore made on the period of time that each new section of gravel had laid in the modified arrester. The details are given in Table 4.

Considering the mean deceleration achieved in all four trials, 3 to 6 in Fig.2, Trials 5 and 6 follow the trend shown for the 18 depth and the difference in the two decelerations might be accounted for, wholly or partly, by the difference in entry speeds. Comparing Trials 3 and 4, however, there is no significant speed difference to affect mean deceleration nor can it be affected by the pitching of the aircraft from the evidence of the instantaneous decelerations shown in Fig.3. It is noticeable that for both trials the pitching is relatively small but that instantaneous deceleration is consistently lower in Trial 3 than in Trial 4. This points to gravel compaction effect over the whole of the arresting distance in Trial 3 and a check on the groove depths made by the main wheel tyres showed that average depths were 8.17 inches and 8.75 inches for Trials 3 and 4 respectively. It is significant that the highest mean decelerations were achieved in Trials 4 and 6 when the aircraft wheels were moving over gravel disturbed both by the previous arrest and the scoop of the vehicle used for re-levelling. On the other hand Trial 3 was made over a gravel surface which had lain undisturbed for four months. In Trial 5, where there was an entry speed effect to take into account, the gravel surface between 389 ft (Trial 3) and 515 ft had lain undisturbed for a similar period and this must have contributed to a fall-off in instantaneous deceleration during this part of the arrest. Unfortunately there was a failure of the camera timing mechanism over the whole of the arrested run and it is not possible to confirm this.

5 CONCLUSIONS

Comparing depths of 12 inches, 18 inches and 30 inches of $\frac{3}{4}$ inch - $\frac{1}{4}$ inch rough irregular gravel, each increase in depth increased the level of

mean deceleration though not in direct proportion. The benefit of extra depth was greatest at lower speeds.

The reduction in main wheel inflation pressures from 260 lb/in^2 to 190 lb/in^2 gave a reduction in mean deceleration but the difference was only slight. The combination of two inflation pressures and a small number of trials on single-wheel undercarriage units is insufficient to enable positive conclusions to be drawn about the likely influence of tyre pressure on the stopping of current civil aircraft.

Compaction of $\frac{3}{4}$ inch - $\frac{1}{4}$ inch rough irregular gravel occurred in consequence of the increased depth and the period of time that it had lain undisturbed. It would appear worthwhile to harrow a gravel arrester about every six months.

Table 1

LIGHTNING ARRESTING TRIALS IN $\frac{3}{4}$ INCH - $\frac{1}{4}$ INCH ROUGH IRREGULAR GRAVEL - MEAN DECELERATIONS

All entries unbraked.

Trial No. and date	AUW lb	Arrester details	Tyre pressures lb/in^2	Entry speed knots	Stopping distance ft	Mean deceleration g
1 15.3.68	26000	30 inch depth from 200 ft to 640 ft	Main 190 Nose 180	62.0	253	0.67
2 21.3.68	26000	30 inch depth from 200 ft to 640 ft	Main 190 Nose 180	70.4	313	0.70
* 3 18.7.68	26000	30 inch depth from 200 ft to 640 ft	Main 260 Nose 240	75.2	389	0.64
4 22.7.68	26000	30 inch depth from 200 ft to 640 ft	Main 260 Nose 240	77.3	349	0.75
5 26.7.68	26000	30 inch depth from 200 ft to 640 ft	Main 260 Nose 240	86.2	515	0.64
6 15.8.68	26000	30 inch depth from 200 ft to 640 ft	Main 260 Nose 240	59.9	218	0.725
7 23.8.68	26000	30 inch depth from 200 ft to 640 ft	Main 190 Nose 180	77.3	393	0.67

*Compaction of deep gravel first suspected.

Table 2

LIGHTNING TRIALS, UNBRAKED, $\frac{3}{4}$ INCH - $\frac{1}{4}$ INCH GRAVEL, 30 INCH DEPTH FROM 200 ft TO 640 ft

Tyre pressures:- Main wheels 260 lb/in^2
Nose wheel 240 lb/in^2

Speeds at specific distances from stopping point in full gravel depth only.

Distance from stopping point	Speed at specified distance from stopping point		Mean speed from common curve	
	22.7.48	15.8.58		
ft	ft/sec	ft/sec	ft/sec	knots
10	23.0	22.5	22.7	13.5
20	37.0	35.3	36.6	21.7
30	46.4	-	46.3	27.5
40	53.5	-	53.5	31.7
50	59.3	-	59.3	35.2
60	64.5	-	64.6	38.3
70	69.3	-	69.3	41.1
80	73.5	-	73.5	43.6
90	77.4	-	77.3	45.9
100	80.6	-	80.8	47.9
110	84.0	-	84.2	50.0
120	87.0	-	87.3	51.8
130	90.3	-	90.2	53.5
140	93.0	-	93.0	55.2
150	95.7	-	95.7	56.8

Table 3

LIGHTNING TRIALS, UNBRAKED, $\frac{3}{4}$ INCH - $\frac{1}{4}$ INCH GRAVEL, 30 INCH DEPTH FROM 200 ft TO 640 ft

Tyre pressures:- Main wheels 190 lb/in^2
Nose wheel 180 lb/in^2

Speeds at specific distances from stopping point in full gravel depth only.

Distance from stopping point	Speed at specified distance from stopping point			Mean speed from common curve	
	15.3.68	21.3.68	23.8.68		
ft	ft/sec	ft/sec	ft/sec	ft/sec	knots
10	22.4	24.7	23.0	23.5	14.0
20	33.6	36.3	35.6	35.7	21.2
30	42.0	45.7	44.6	45.0	26.7
40	48.2	53.0	51.8	52.4	31.1
50	54.0	59.4	58.0	58.7	34.8
60	-	64.6	63.5	64.3	38.2
70	-	69.0	68.4	68.7	40.8
80	-	73.0	72.7	73.2	43.5
90	-	76.6	77.0	77.2	45.8
100	-	80.3	80.7	80.7	47.9
110	-	-	84.3	84.2	50.0
120	-	-	87.2	87.2	51.8
130	-	-	90.0	90.0	53.4
140	-	-	92.6	92.7	55.0
150	-	-	95.2	95.2	56.5
160	-	-	97.6	97.7	58.0
170	-	-	100.0	100.0	59.4
180	-	-	102.0	102.0	60.6

Table 4

HISTORY OF R.A.E. ARRESTER MODIFICATIONS FOR AIRCRAFT TRIALS. $\frac{3}{4}$ INCH - $\frac{1}{4}$ INCH ROUGH IRREGULAR GRAVEL

Modification dates

Gravel laid 12 inches deep, 240 ft long	-	12.5.66
Arrester extended 12 inches deep, 400 ft long	-	6.7.66
Gravel depth increased to 18 inches, 400 ft long	-	18.10.66
Gravel depth increased to 30 inches, 400 ft long	-	1.5.67
Arrester extended 30 inches deep, 640 ft long	-	15.6.67

Laying period up to 18.7.68 when gravel compaction first suspected

The first 12 inches of gravel from entry to 240 ft	-	26 months
The first 12 inches of gravel from 240 ft to 400 ft	-	24 months
The extra 6 inches of gravel from entry to 400 ft	-	21 months
The extra 12 inches of gravel from entry to 400 ft	-	14 months
The first 30 inches of gravel from 400 ft to 640 ft	-	13 months

REFERENCE

No.	Author	Title, etc.
1	E. Bade	Soft-ground arresting of civil aircraft. R.A.E. Technical Report 68032 (1968)

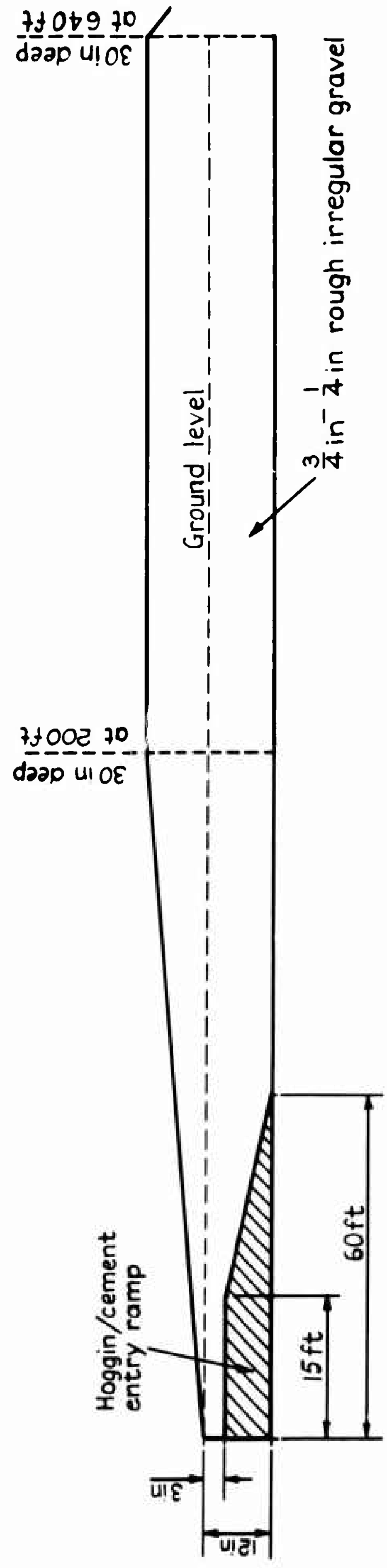

Fig. 1 R.A.E. experimental arrester, gravel depth pattern

Fig. 2

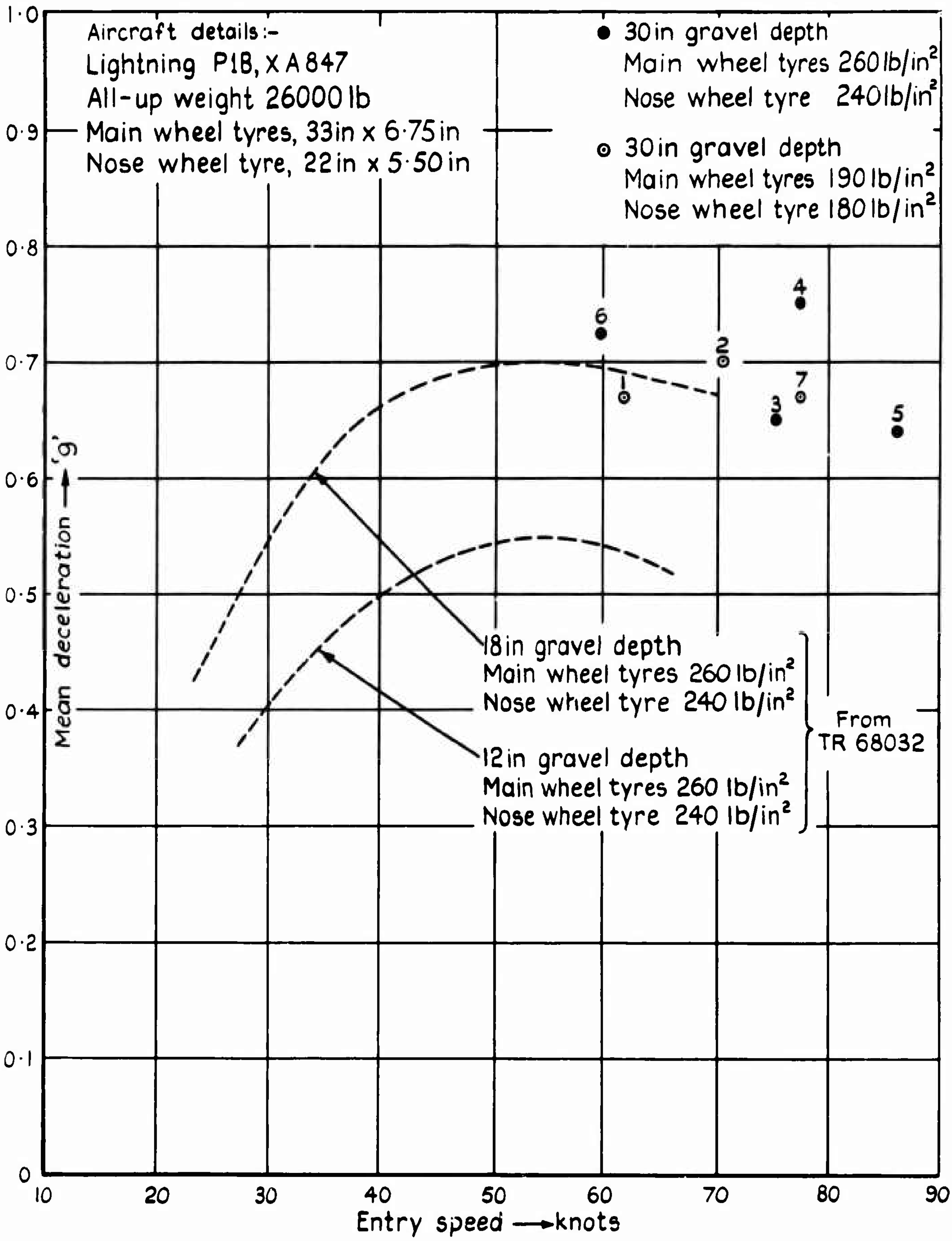

Fig. 2 Lightning, unbraked, influence of gravel depth and tyre pressure on mean deceleration

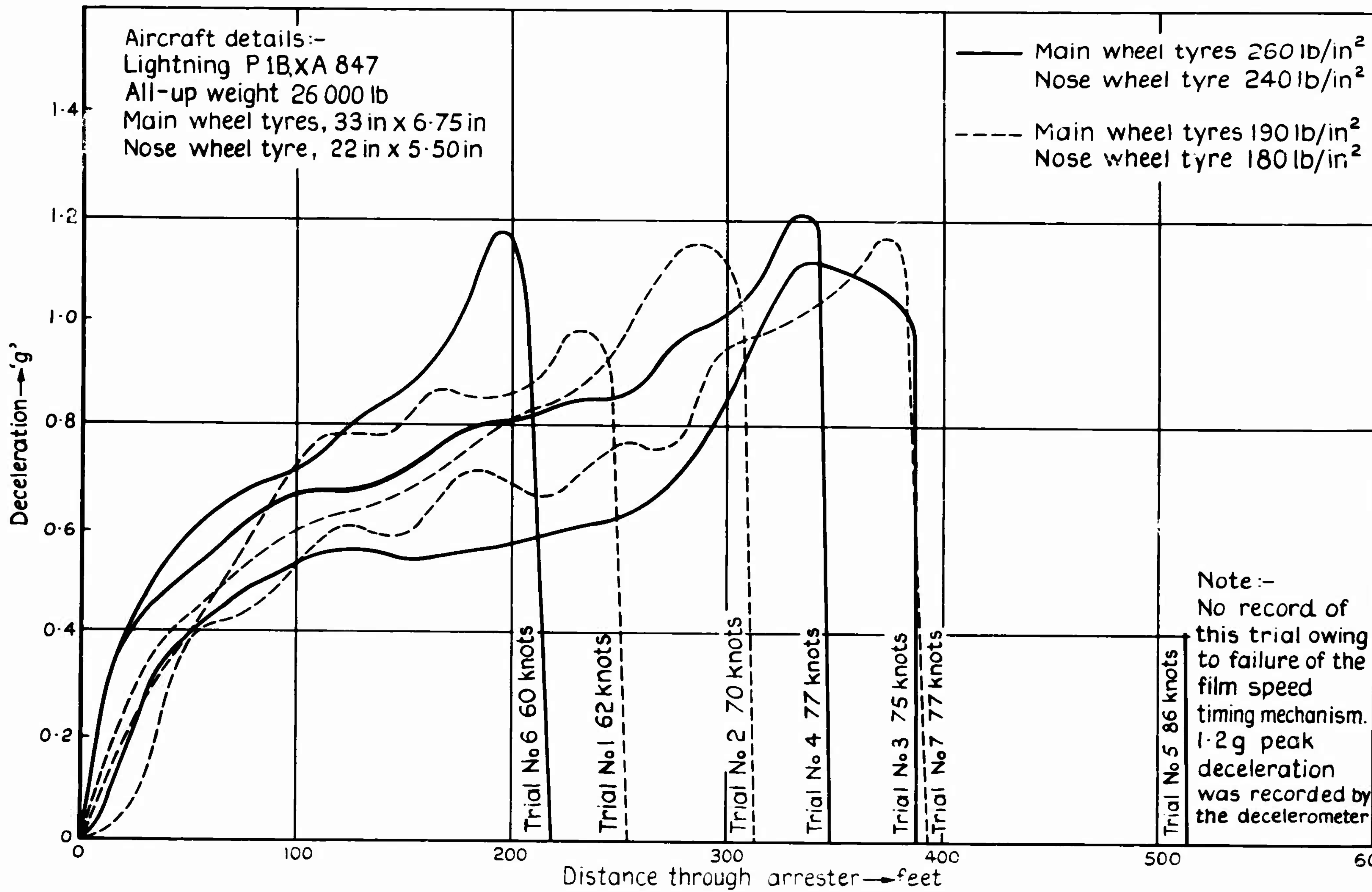

Fig. 3 Lightning, unbraked, deceleration/distance curves, $\frac{3}{4}$ in

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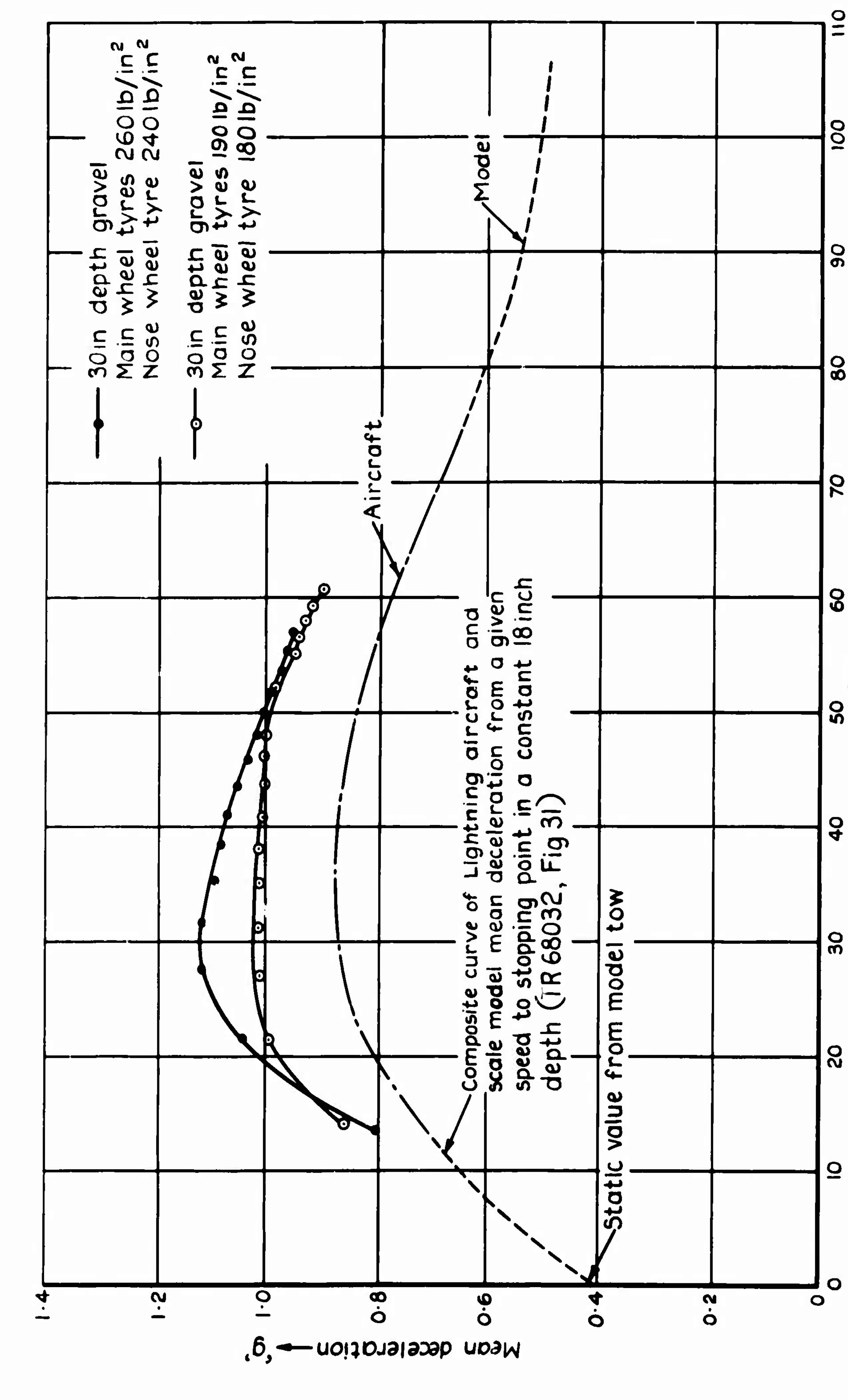

Fig. 4 Lightning, unbraked, composite curves of mean deceleration in a constant 30 in gravel depth

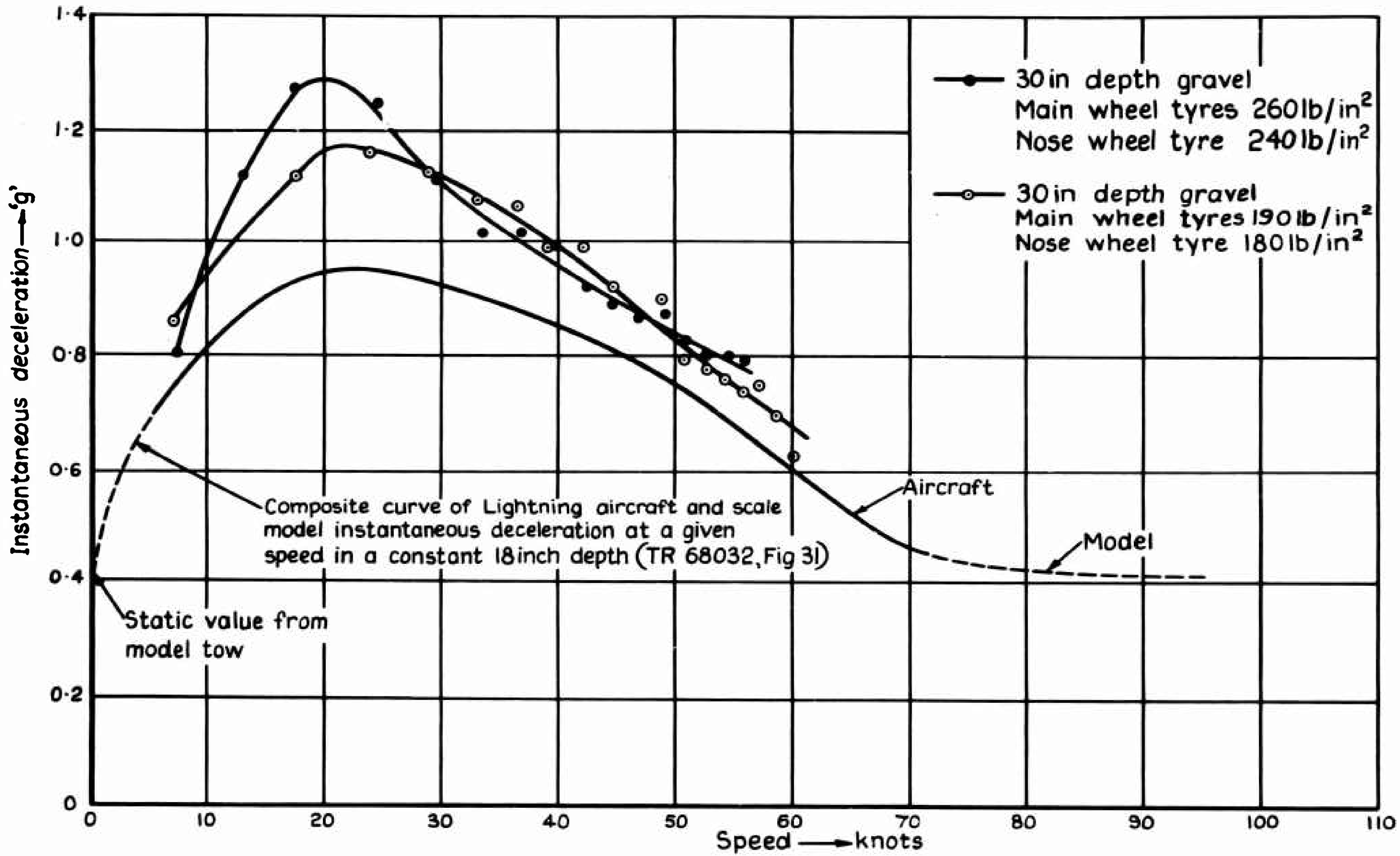

Fig. 5 Lightning, unbraked, composite curves of instantaneous deceleration in a constant 30 in gravel depth